

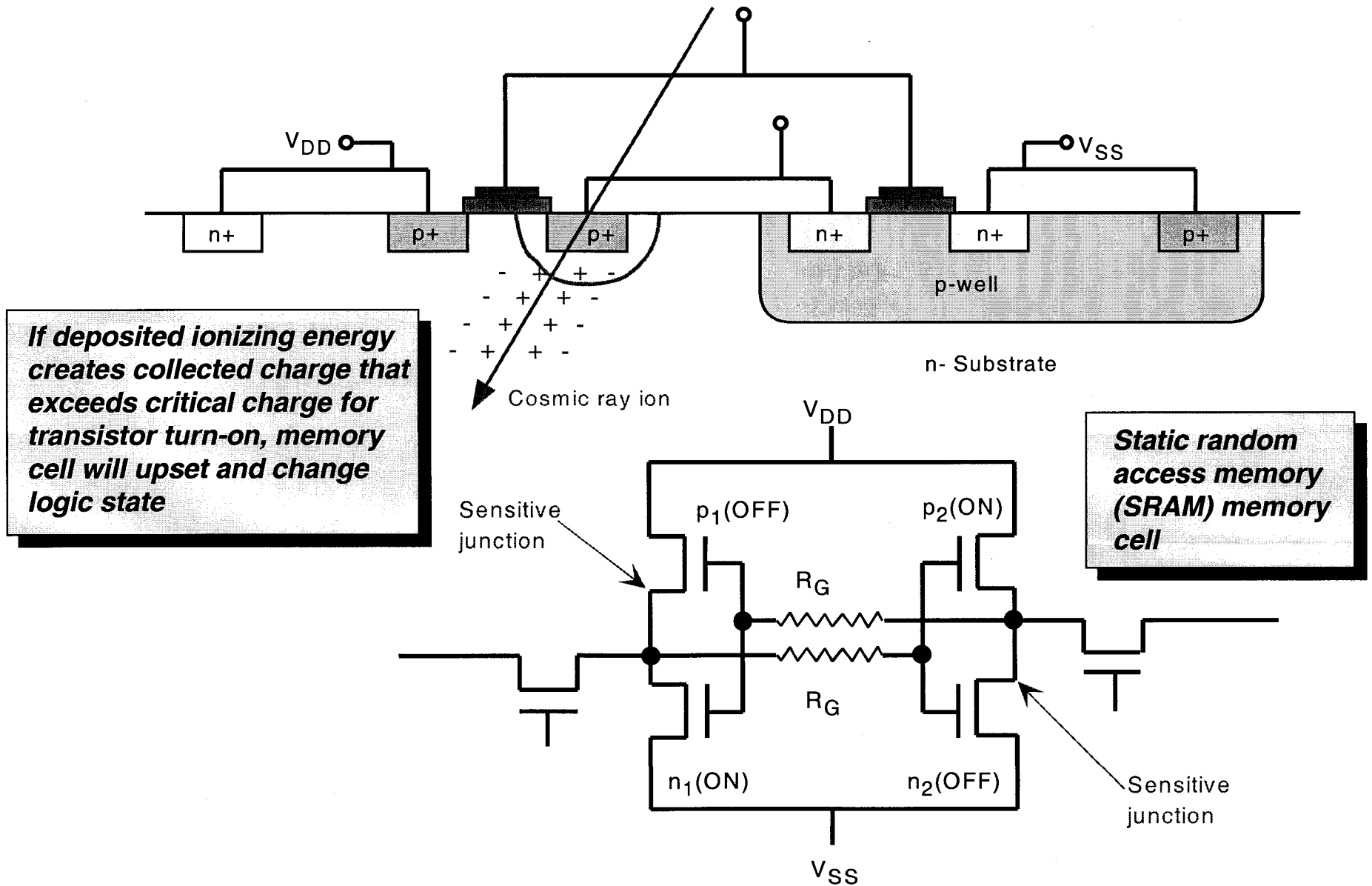


A Brief History of Memory in Space from an SEE (Single Event Effects) Perspective

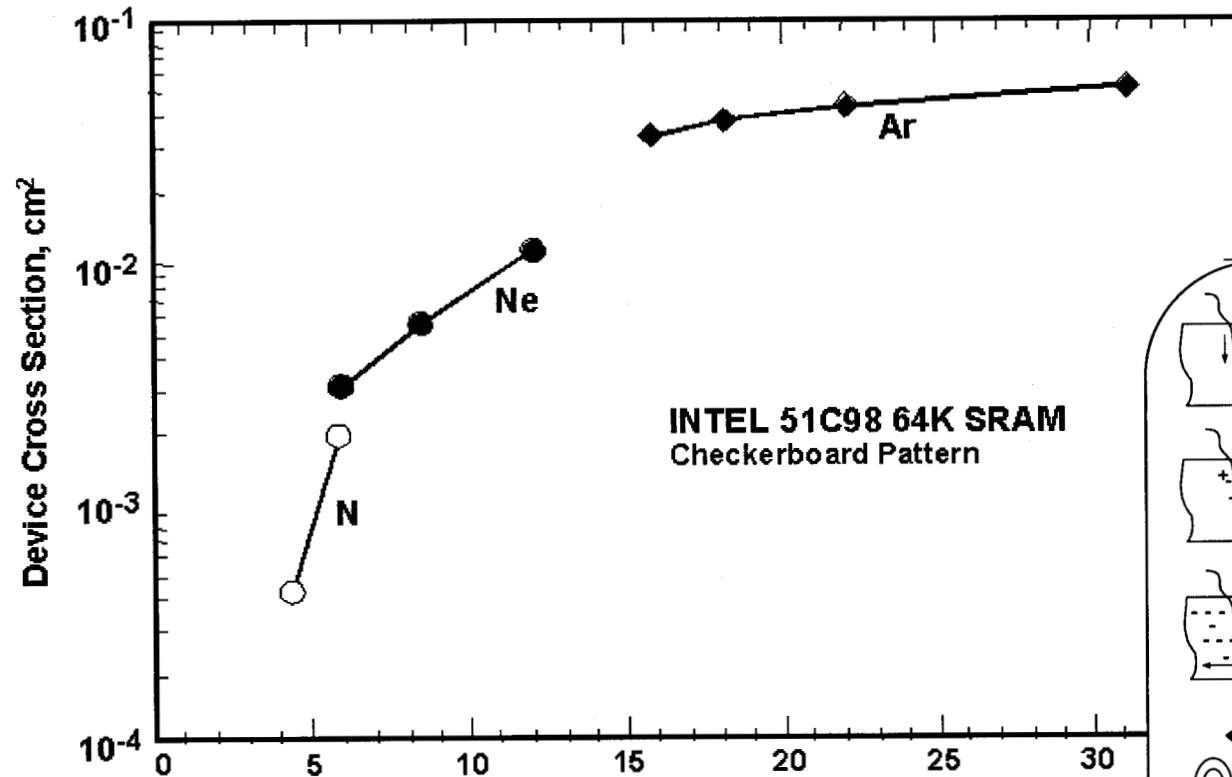
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Work performed by the Jet Propulsion Lab, California Institute of Technology under contract with the National Aeronautics and Space Administration

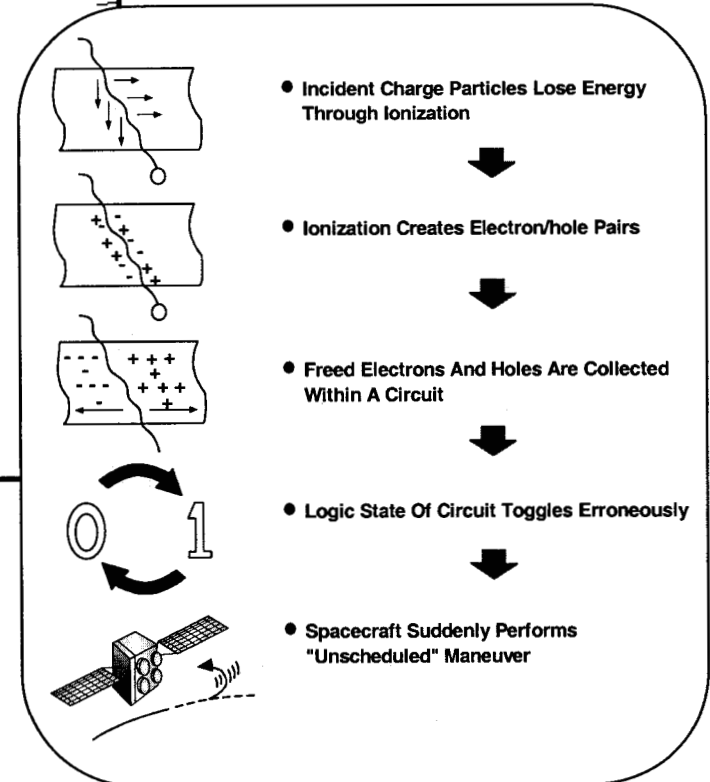
Single Event Upset (SEU) Mechanism



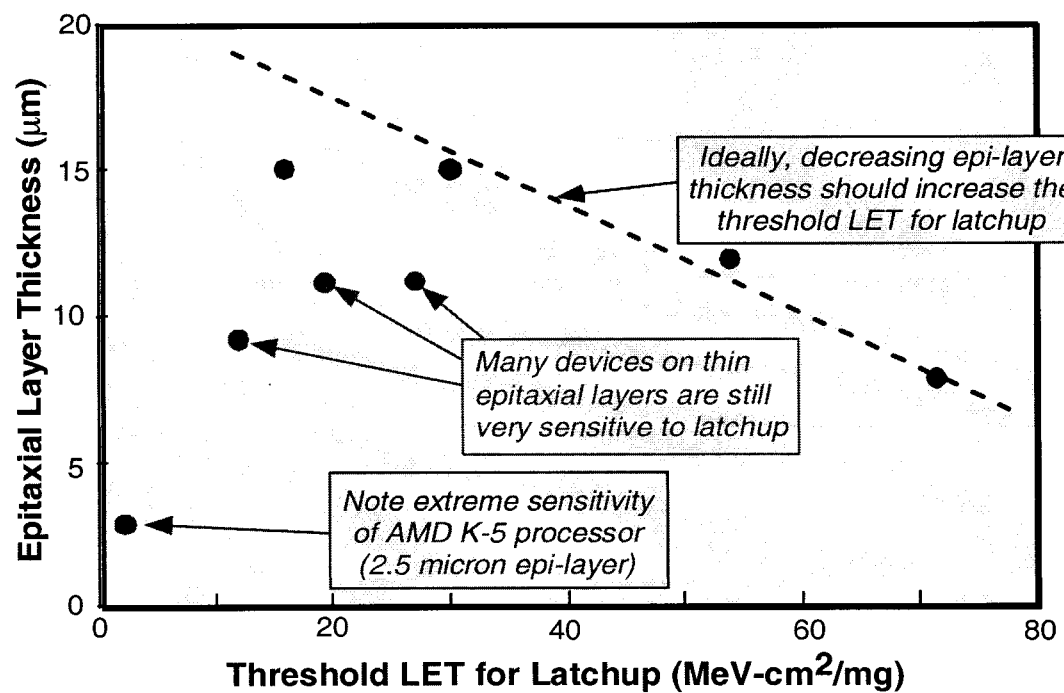
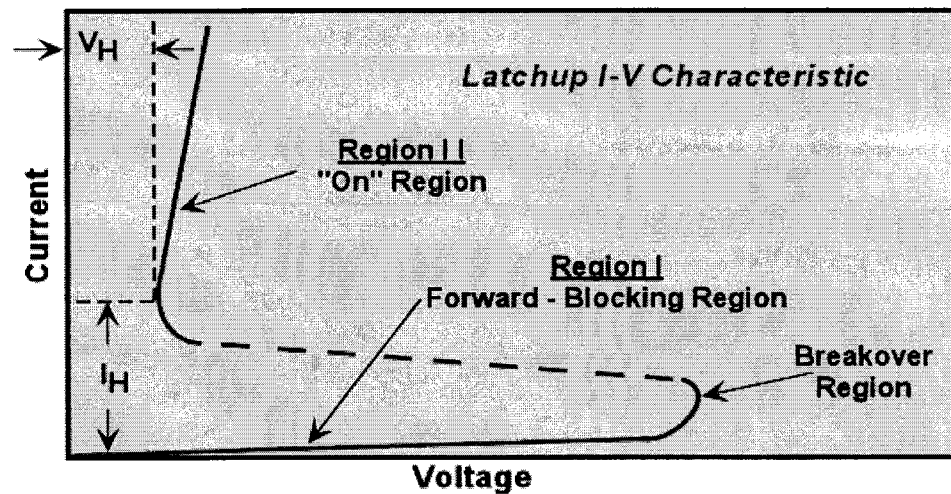
Single Event Effects



Example of single event cross section data

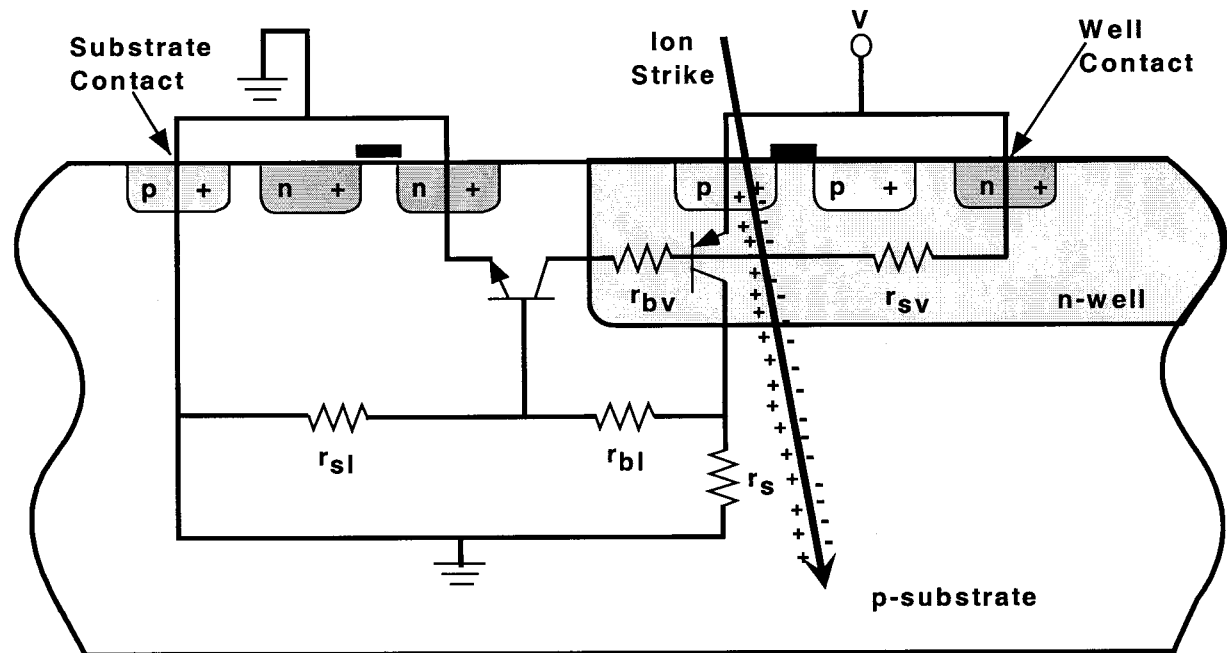


Single Event Latchup (SEL)



Single Event Latchup (SEL)

Initial Triggering Action:
Ion-induced current flows from well contact to substrate contact, and produces a voltage drop within the well, which, in turn, forward biases the parasitic vertical bipolar transistor



Existence of parasitic vertical and horizontal bipolar transistors ($p-n-p-n$) allows regenerative structure to exist and makes circuit susceptible to latchup

When the product of the gains of these transistors is greater than 1, an SCR-like action takes place and latchup can occur

Notes:

Definition of SEE: An observable electrical disturbance from an individual ionizing particle strike

Use of “pure” commercial devices is increasing because:

- **Most rad-hard foundries have closed**
- **Commercial devices are more attractive to designers, more dense and lower power**

Use of commercial devices is possible because:

- **Variety of mfrs. increase the chance of finding a fortuitously rad-hard device**
- **VLSI makes viable complex error correction circuitry**

1970s

**Bipolar SRAM ICs
and
Early CMOS SRAMs**

Examples: 93L422 2k bits - many missions incl. Topex/Poseidon
CD4061 256 bits - Voyager

SEEs: Cell upsets

1980s

Rad-hard CMOS SRAMs

Examples: TCC244 1k bits (Sandia foundry) - Galileo
 6516 16k bits (Harris foundry) - Magellan

SEEs: **Cell upsets**
 Latchup (fixed by rad-hard foundries)
 Micro-dose stuck bits

1990s

DRAMs

Examples: MSM514400 4Mb DRAMs - Cassini
Luna-C,-E 16Mb DRAMs - Pathfinder, Seawinds,...

SEEs: Cell upsets - error correcting circuitry fixes
Multiple bit upset } problematic for ECC
Stuck bits }
Latchup - by luck, some mfrs. immune
Functional interrupts

2000s

Flash Memory

Examples: KM 29U128 128Mbit
- X2000: Europa Orbiter, Solar Probe, Pluto/Kuiper Express

SEEs: **State Machine Upsets**
 Lockups
 Block destruction

Earlier...

Core Magnetic Memory

Examples: Plated Wire - Viking I & II

SEEs:

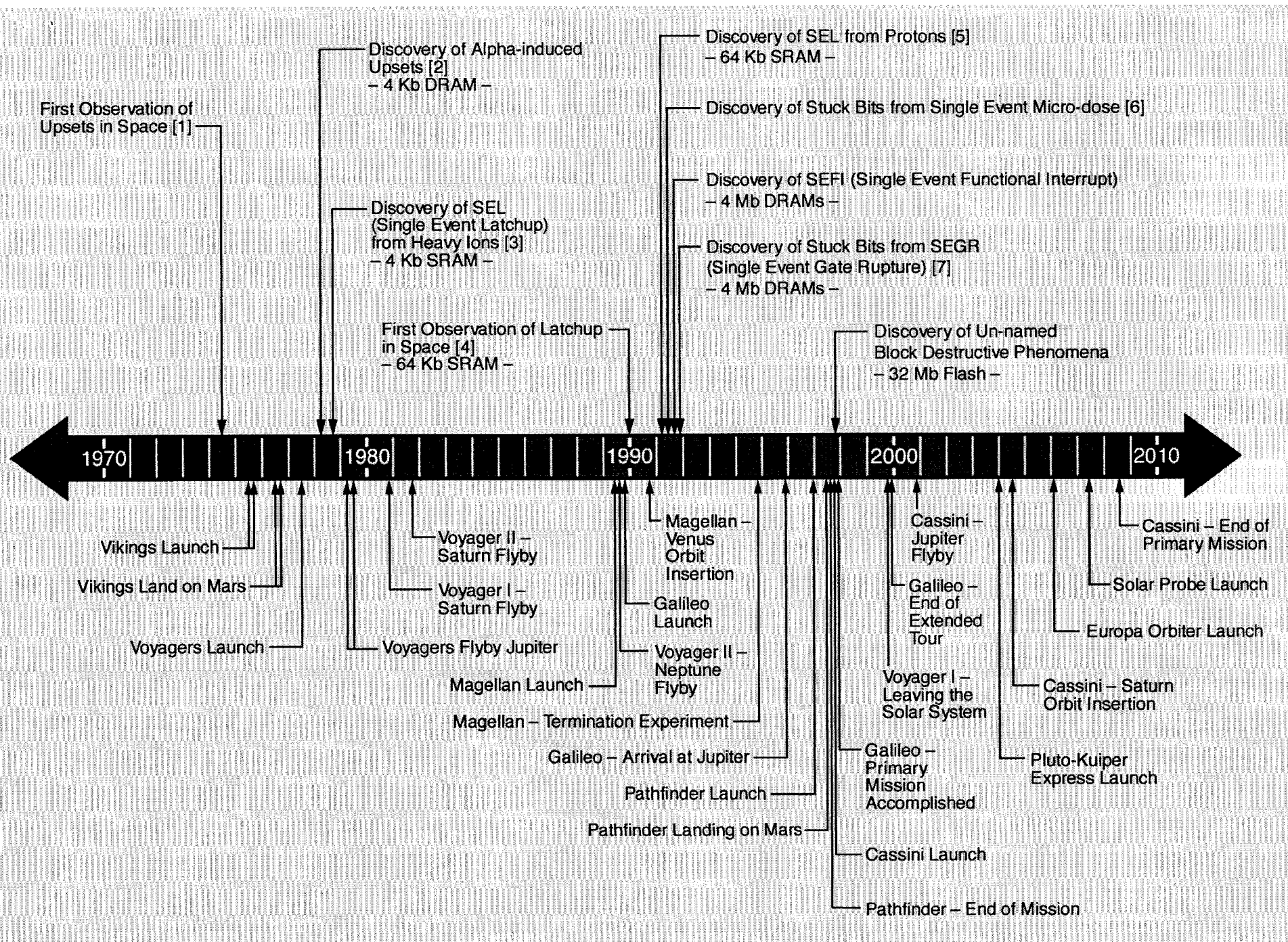
None!

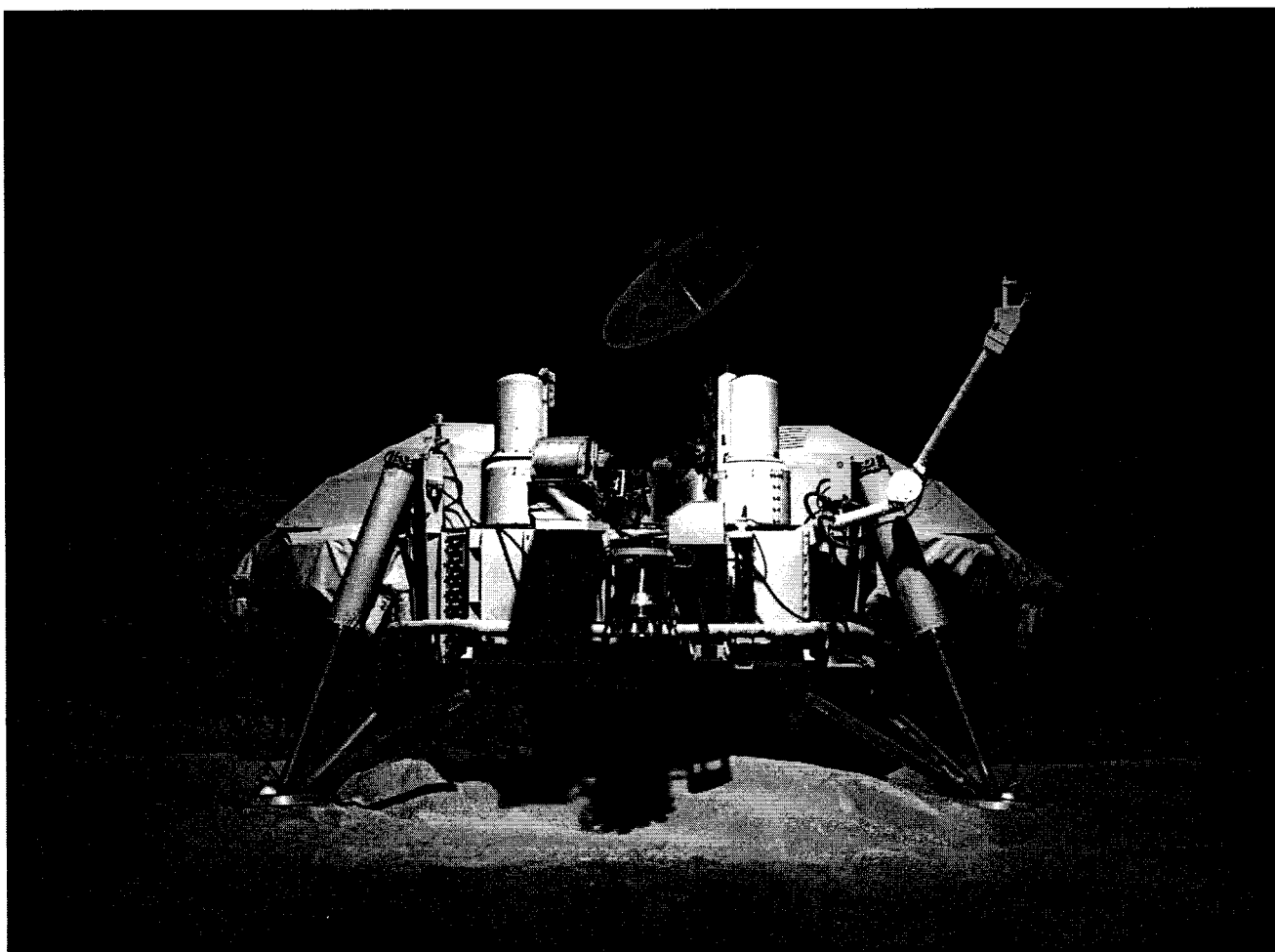
Further Out...

Advanced Non-Volatile Technologies (?)

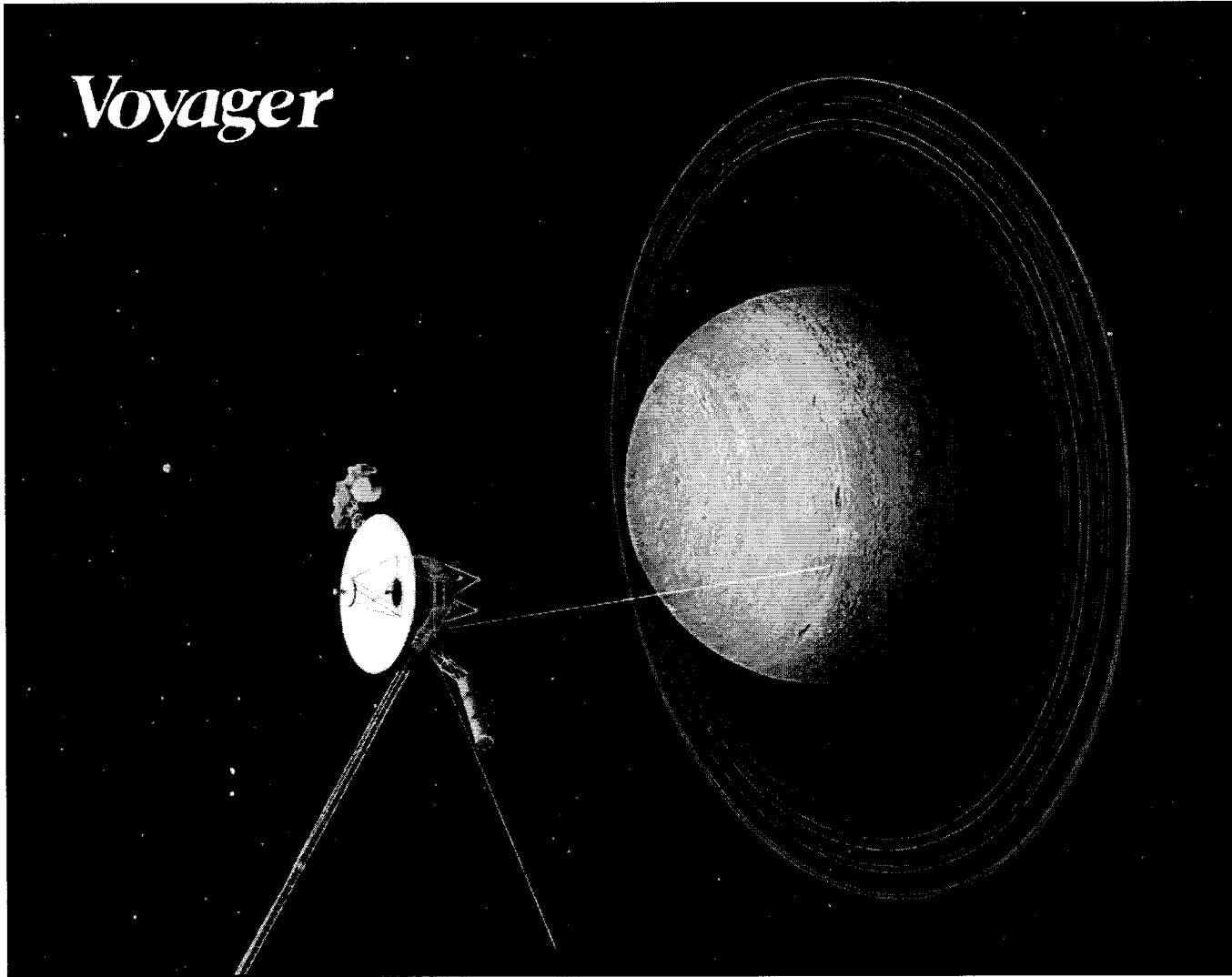
Possibilities: Ferro-electric RAMs - sets and senses dielectric polarization
 GMR (Giant Magneto-resistive) RAMs
 C-RAM (based on chalcogenide)

SEEs: **To be found**

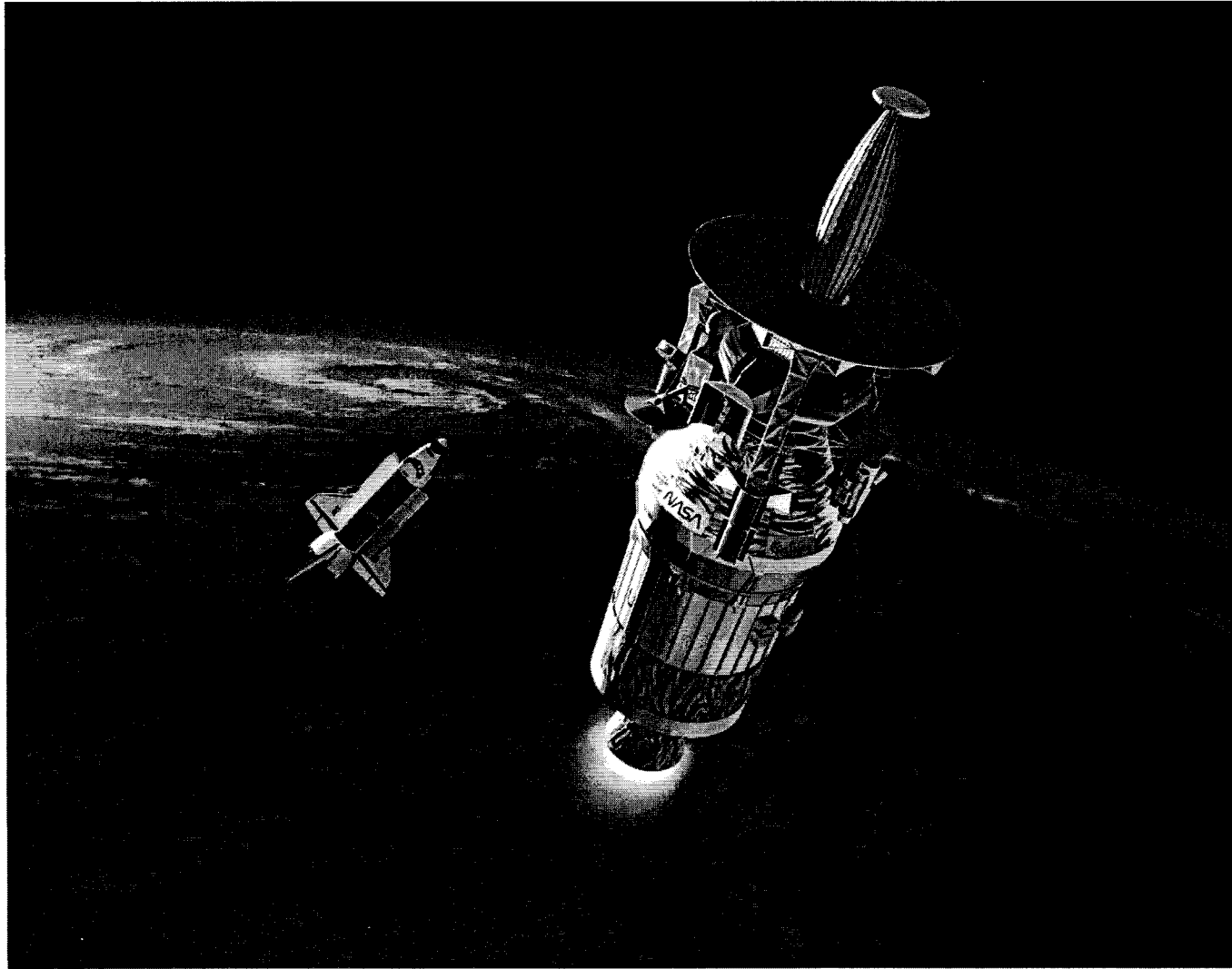


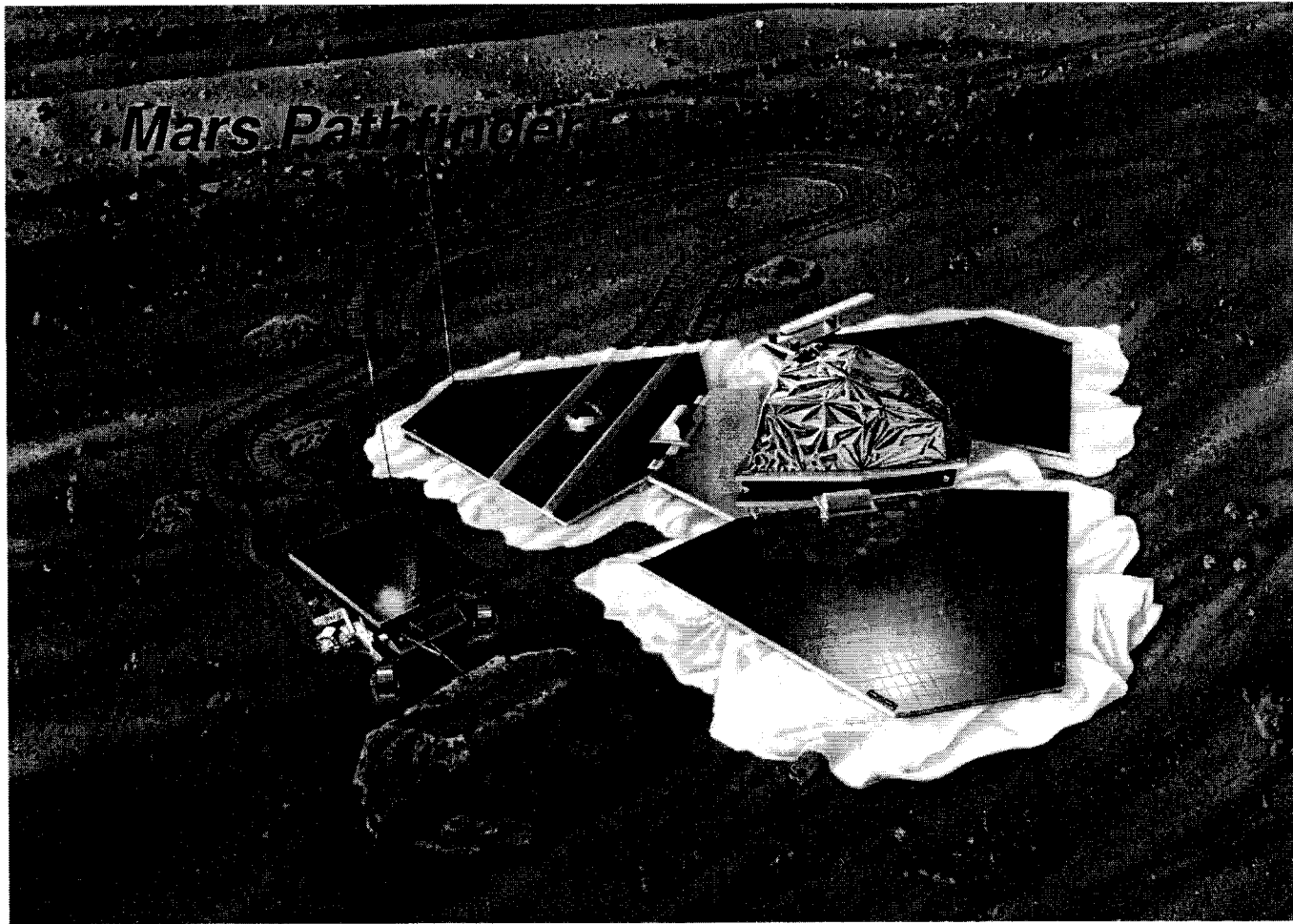


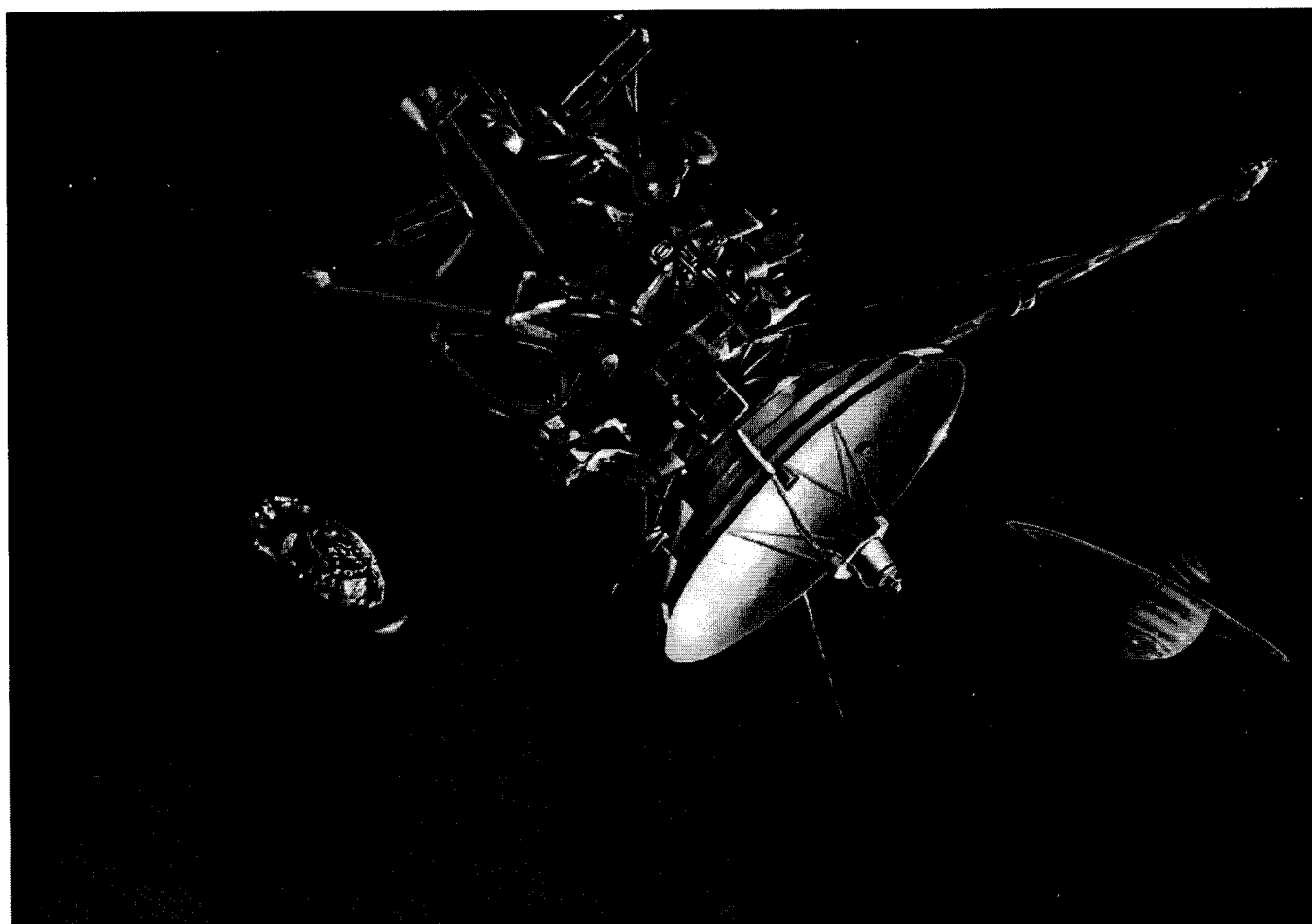
Voyager















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